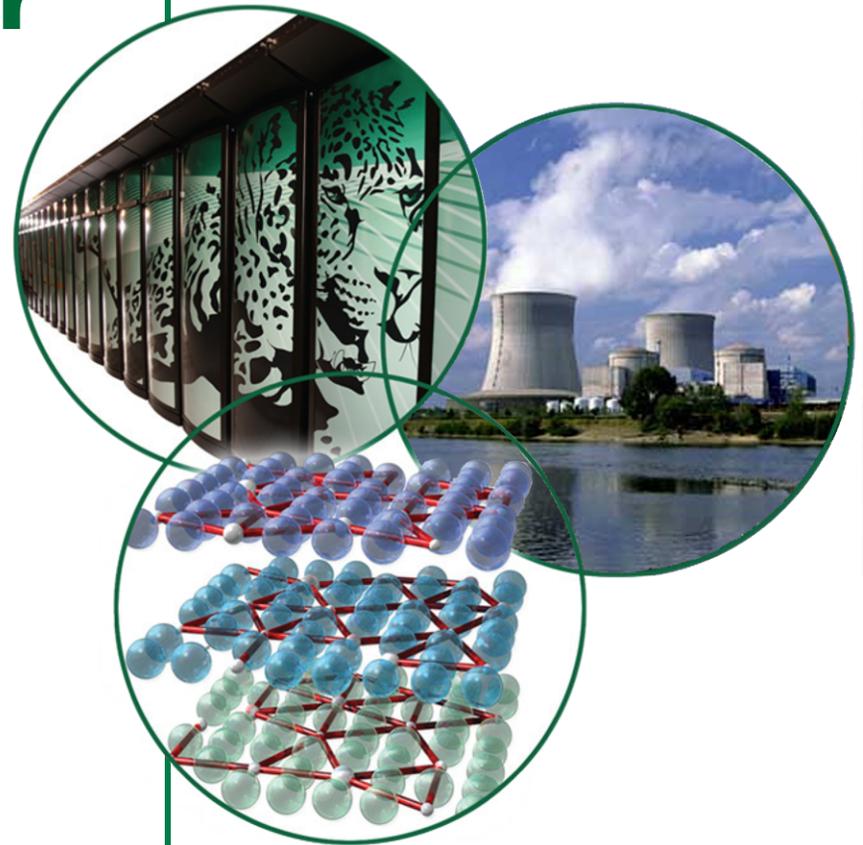


# SmAHTR – the Small Modular Advanced High Temperature Reactor

Presented to  
**DOE FHR Workshop**  
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U.S. DEPARTMENT OF  
**ENERGY**

 **OAK RIDGE NATIONAL LABORATORY**  
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# Presentation overview

- SmAHTR design objectives
- Preliminary SmAHTR concept
- SmAHTR concept optimization and design trades
- Principal SmAHTR development challenges

## SmAHTR development is a team effort:

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E. C. Bradley

M. S. Cetiner

# **SmAHTR is the product of ORNL's ongoing investigation of the FHR design space**

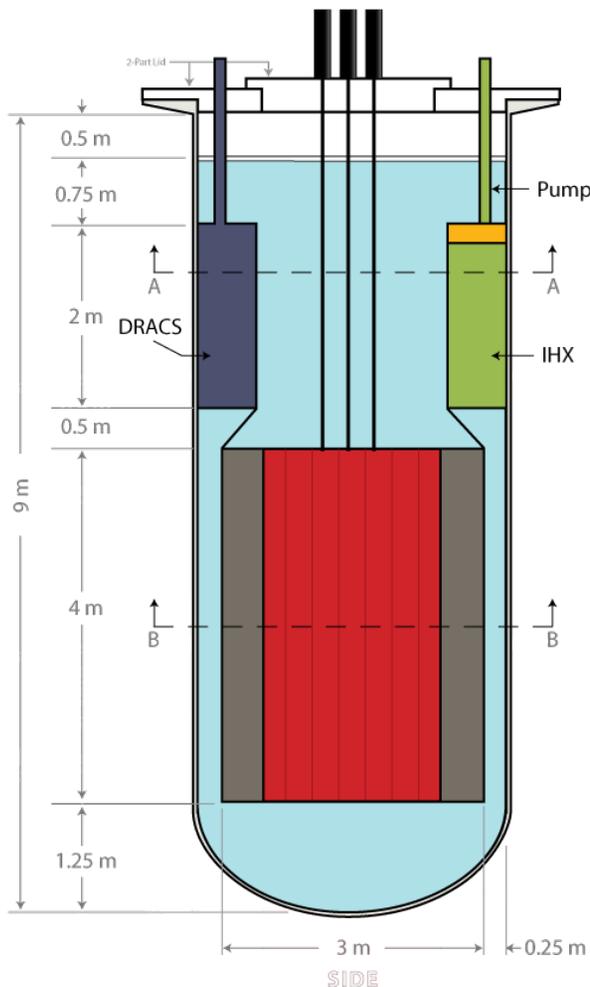
- **Reactor power level**
- **Physical size**
- **System complexity**
- **Operating temperatures**
- **Fuel forms**
- **Material classes**
- **Economics**
- **Safety**

# **SmAHTR design objectives target both electricity and process heat production**

- **Initial concept operating temperature of 700 °C with future evolution path to 850 °C and 1000 °C**
- **Thermal size matched to early process heat markets**
- **Integral system architectures compatible with remote operations**
- **Passive decay heat removal**
- **Truck transportable**

# SmAHTR is an “entry-level” very-high-temperature reactor (VHTR)

## Overall System Parameters



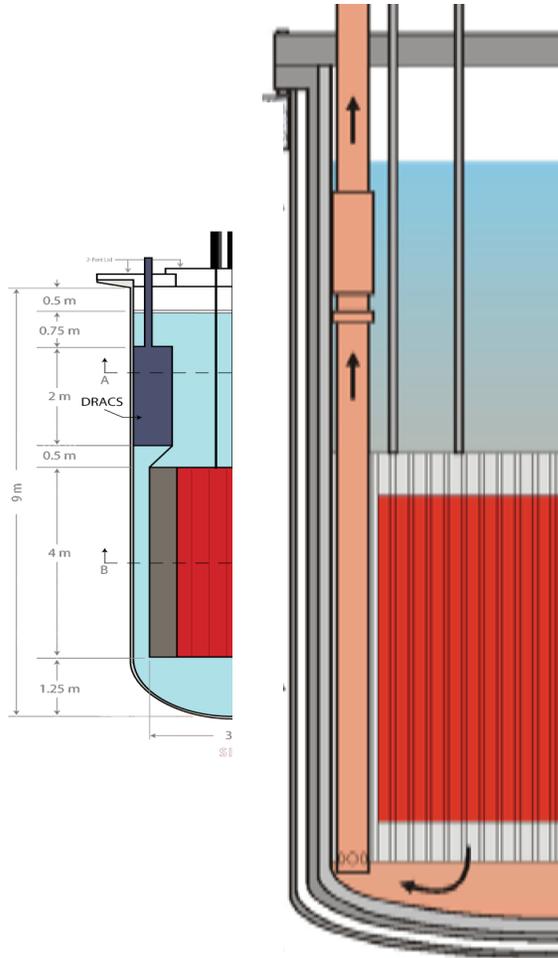
Parameter	Value
Power (MWt / MWe)	125 / 50+
Primary Coolant	LiF-BeF <sub>2</sub>
Primary Pressure (atm)	~1
Core Inlet Temperature (°C)	650
Core Outlet Temperature (°C)	700
Core coolant flow rate (kg/s)	1020
Operational Heat Removal	3 – 50% loops
Passive Decay Heat Removal	3 – 50% loops
Power Conversion	Brayton
Reactor Vessel Penetrations	None

# SmAHTR is small...

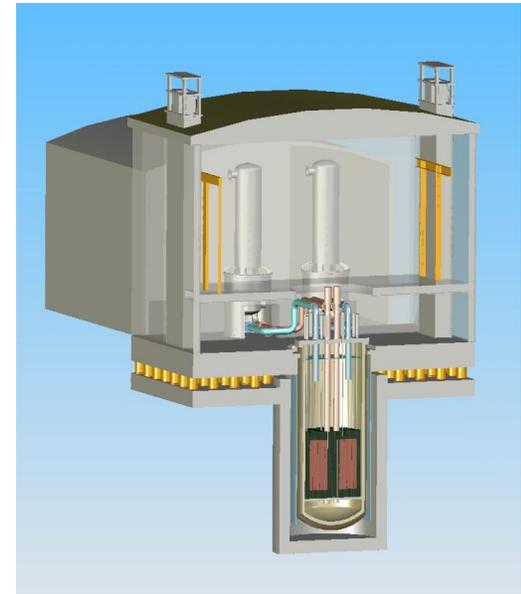
## SmAHTR



## Small

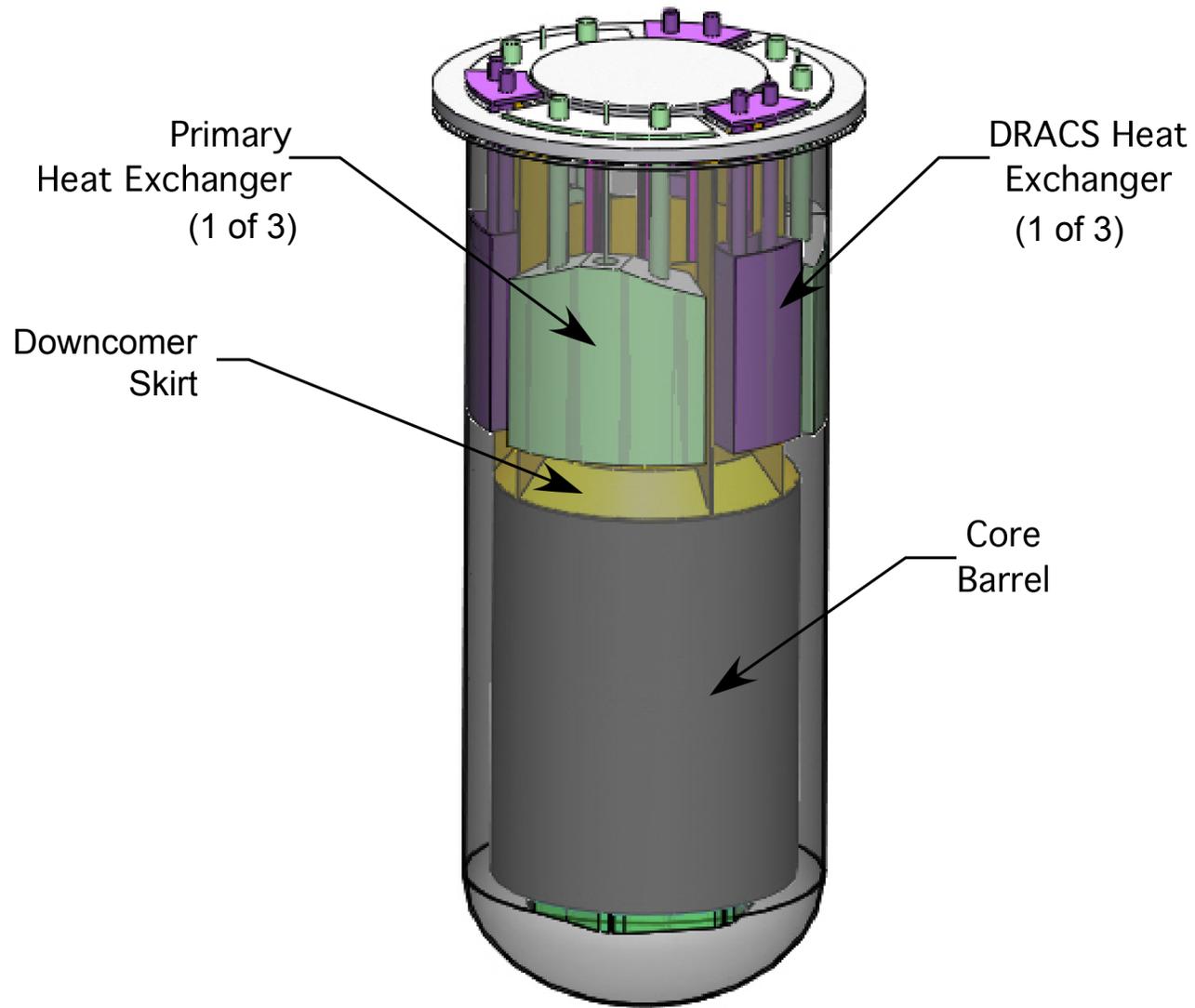


## AHTR

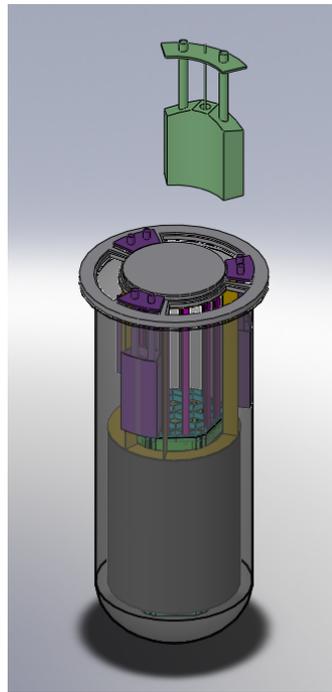


## Large

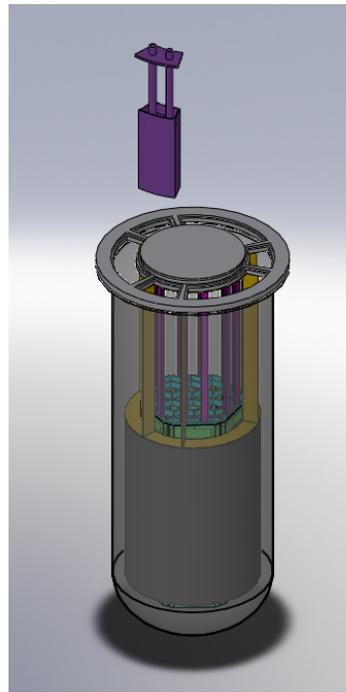
# SmAHTR is a cartridge-core, integral-primary-system FHR



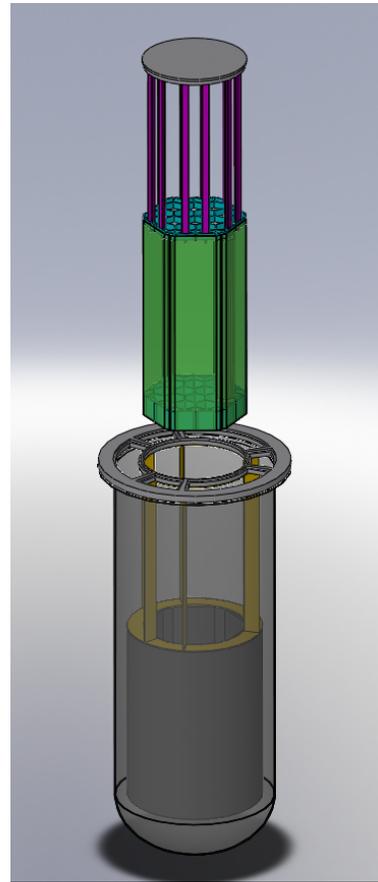
# SmAHTR primary system mechanical design enables rapid component servicing



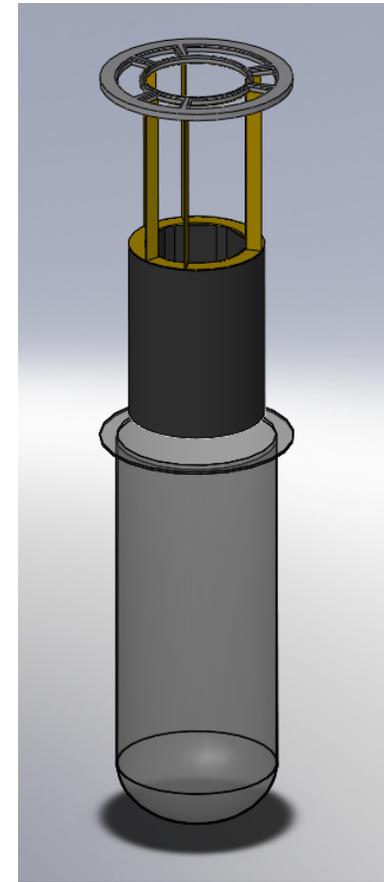
IHX removal



DRACS removal



Core Removal

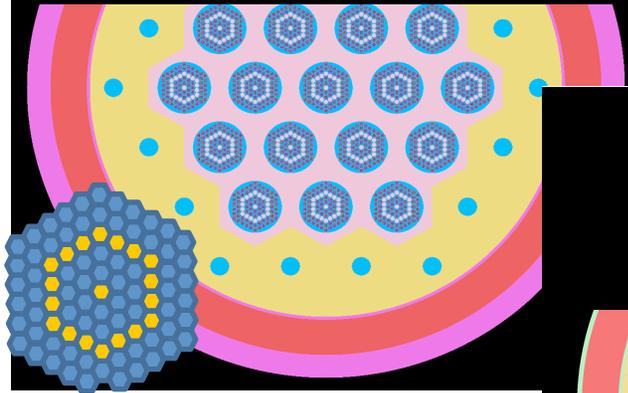


Reflector Removal

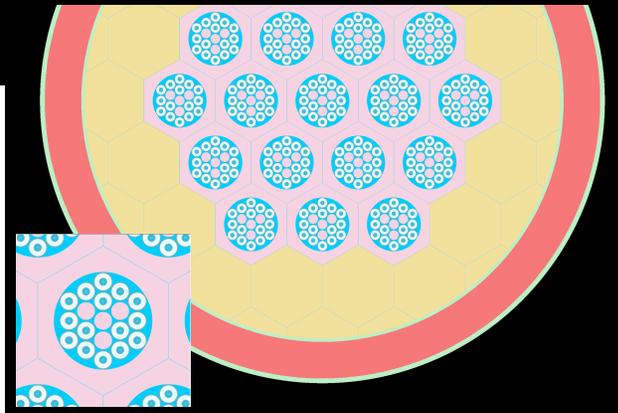
Note: downcomer skirt not shown

# Three fuel assembly concepts are under consideration (control rods not shown)

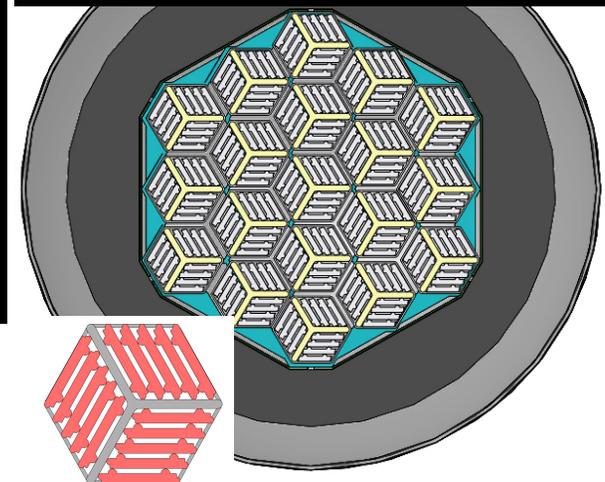
2.2 cm dia. Solid cylindrical compact stringers



6 cm dia. Annular cylindrical compact stringers

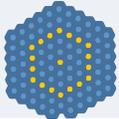


23 cm wide Hex-plate fuel assemblies



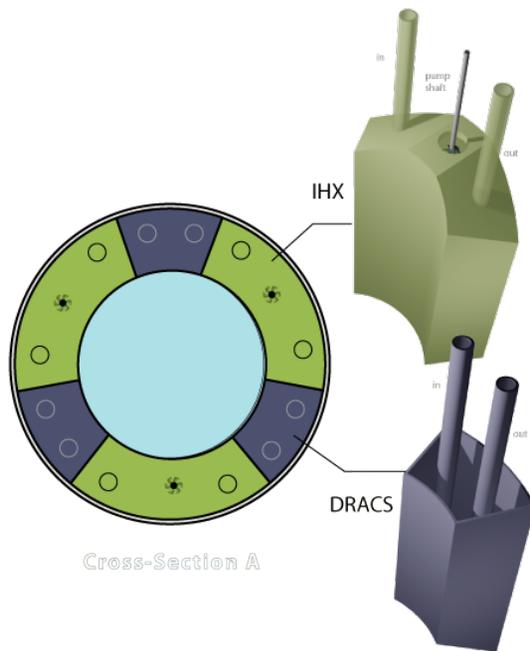
- Cylindrical fuel assembly O.D. = 34 cm
- Plate fuel assembly O.D. = 43 cm

# Cylindrical annular compacts are current SmAHTR reference fuel concept

SmAHTR Fuel / Core Parameter	Option 1	Option 2 (Reference)	Option 3
Fuel Assembly Design	Solid Cylindrical Compact Stringers in Hex Graphite Blocks	Annular Cylindrical Compact Stringers In Hex Graphite Blocks	Flat Fuel Plates in Hex Configuration
UCO fuel kernal diameter (microns)	425	500	500
Number fuel columns or assemblies	19	19	19
Number fuel pins / plates per column or fuel element	72 	15 	12 
Number graphite pins or plates per column or fuel element	19	4	9
Initial Fissile Mass (kg)	195	357	443
Total Heavy Metal (kg)	987	1806	2240
Enrichment	19.75%	19.75%	19.75%
Avg. Power Density (MW/m <sup>3</sup> )	9.4	9.4	9.4
Refueling Interval (yr)	2.5	4.0	3.5

# SmAHTR employs “two-out-of-three” heat transport design philosophy

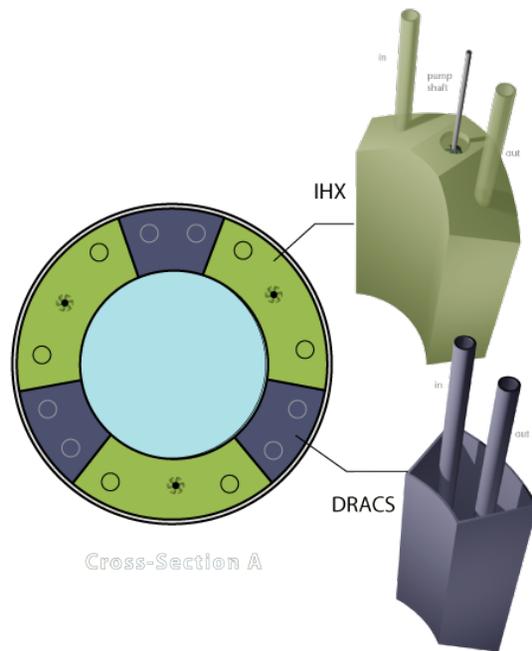
## Intermediate Heat Transport Loop Parameters



Parameter	Value
Number of Primary Heat Exchangers (PHX)	3
Number PHX needed for full power operation	2
PHX Design Concept	Single-pass, tube-in-shell
Primary Coolant	LiF-BeF <sub>2</sub>
Primary Inlet Temperature (°C)	700
Primary Outlet Temperature (°C)	650
Primary flow rate (kg/s)	350 (each)
Secondary Coolant	LiF-NaF-KF
Secondary Inlet Temperature (°C)	582
Primary Outlet Temperature (°C)	610
Secondary flow rate (kg/s)	800 (each)

# SmAHTR employs “two-out-of-three” passive decay heat removal

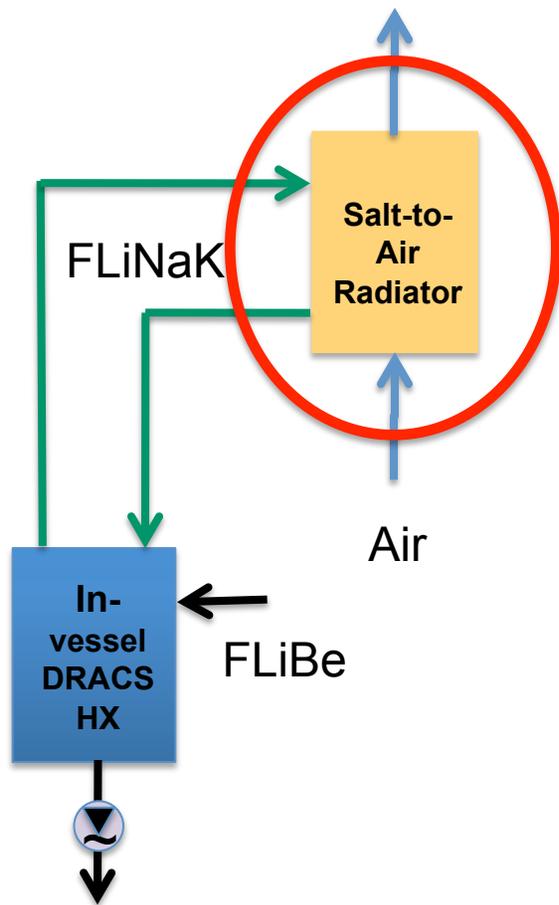
## In-vessel Passive Decay Heat Removal System Parameters



In-vessel DRACS HX Parameter	Value
Number DRACS in-vessel heat exchangers	3
Number DRACS loops needed for full power operation	2
DRACS Salt-to-Salt Design Concept	Single-pass, tube-in-shell
Primary Coolant	LiF-BeF <sub>2</sub>
Secondary Coolant	LiF-NaF-KF

# SmAHTR DRACS utilizes salt-to-air, natural convection heat rejection

## Ex-vessel Passive Decay Heat Removal System Parameters



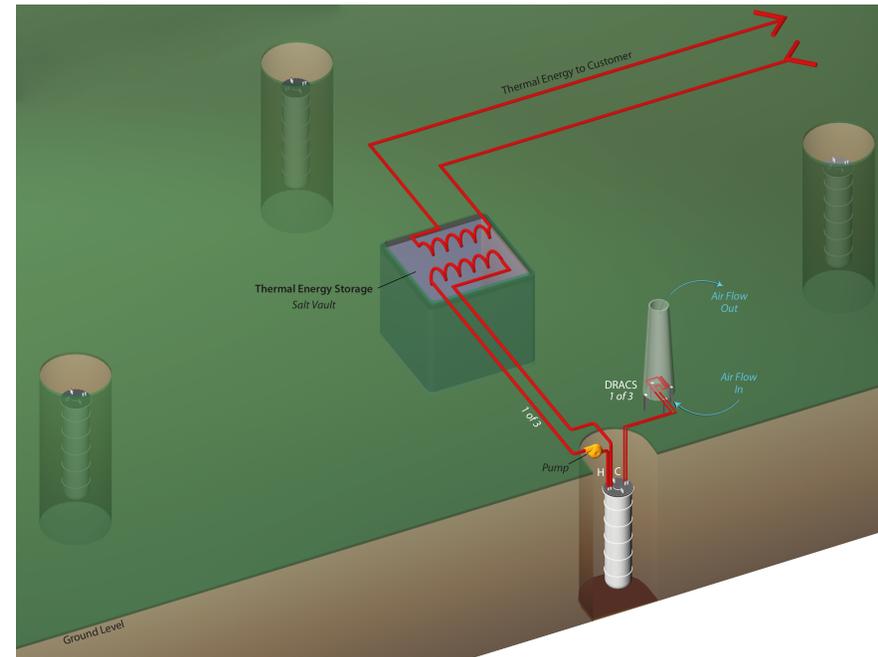
Ex-vessel DRACS HX Parameter	Value
Number DRACS	3
Number DRACS needed for full power operations	2
DRACS Salt-to-Air Design Concept	Vertical finned tube radiator
Primary Coolant	LiF-NaF-KF
Air Flow Area (m <sup>2</sup> )	4
In-vessel HX – to – air HX riser height (m)	8
Total chimney height (m)	12

# **SmAHTR is good match with Brayton power conversion technologies**

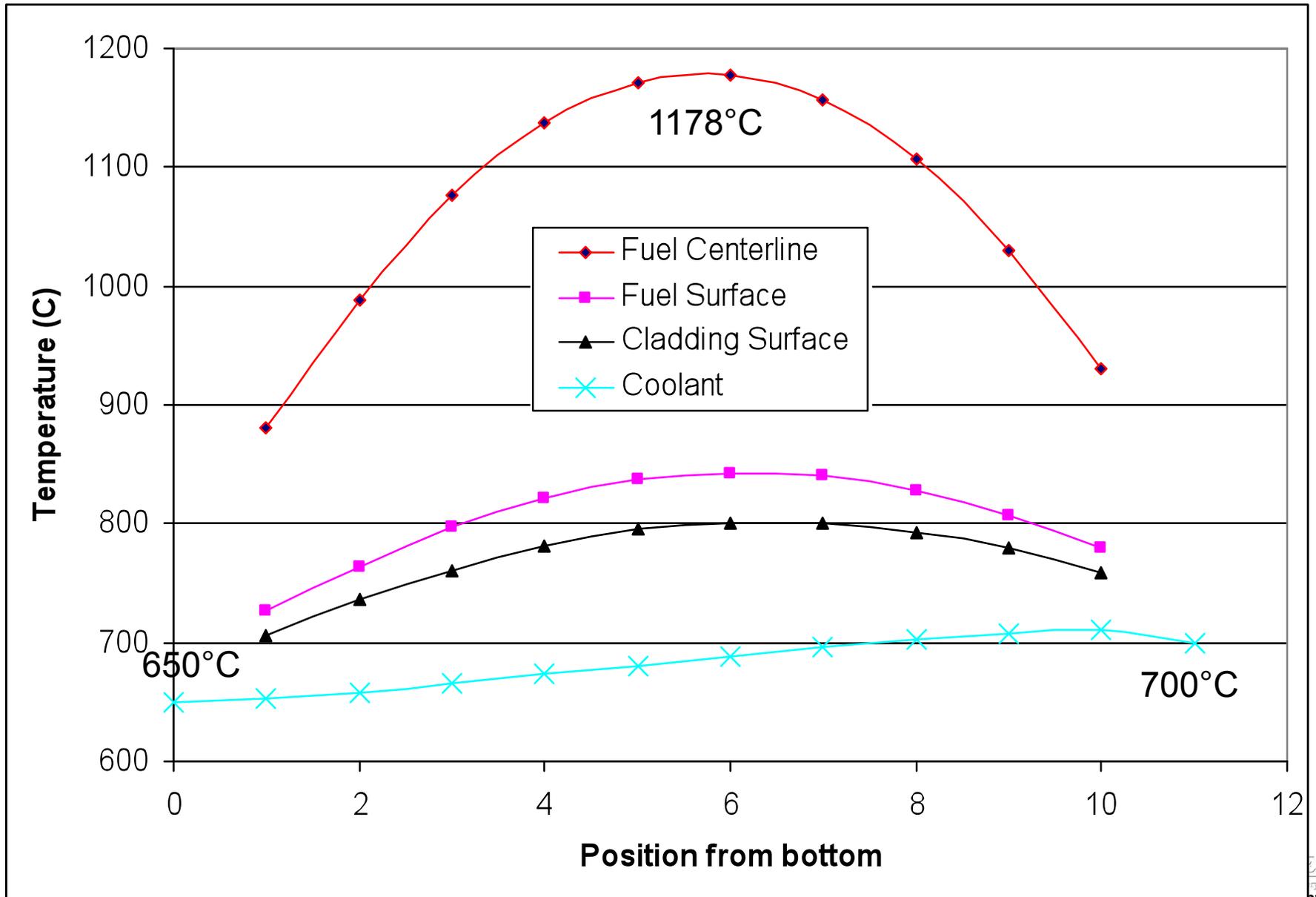
- **Options**
  - Standard closed
  - Supercritical closed
  - Open air (similar to ANP & HTRE)
- **Issues to consider**
  - Physical size & weight
  - Multi-unit clustering
  - Heat exchanger pressure differentials
  - Efficiency and scalability to higher temperatures
  - Tritium leakage
  - Compatibility with dry heat rejection
- **Trade study underway**

# SmAHTR thermal energy storage system employs “salt vault” thermal storage concept

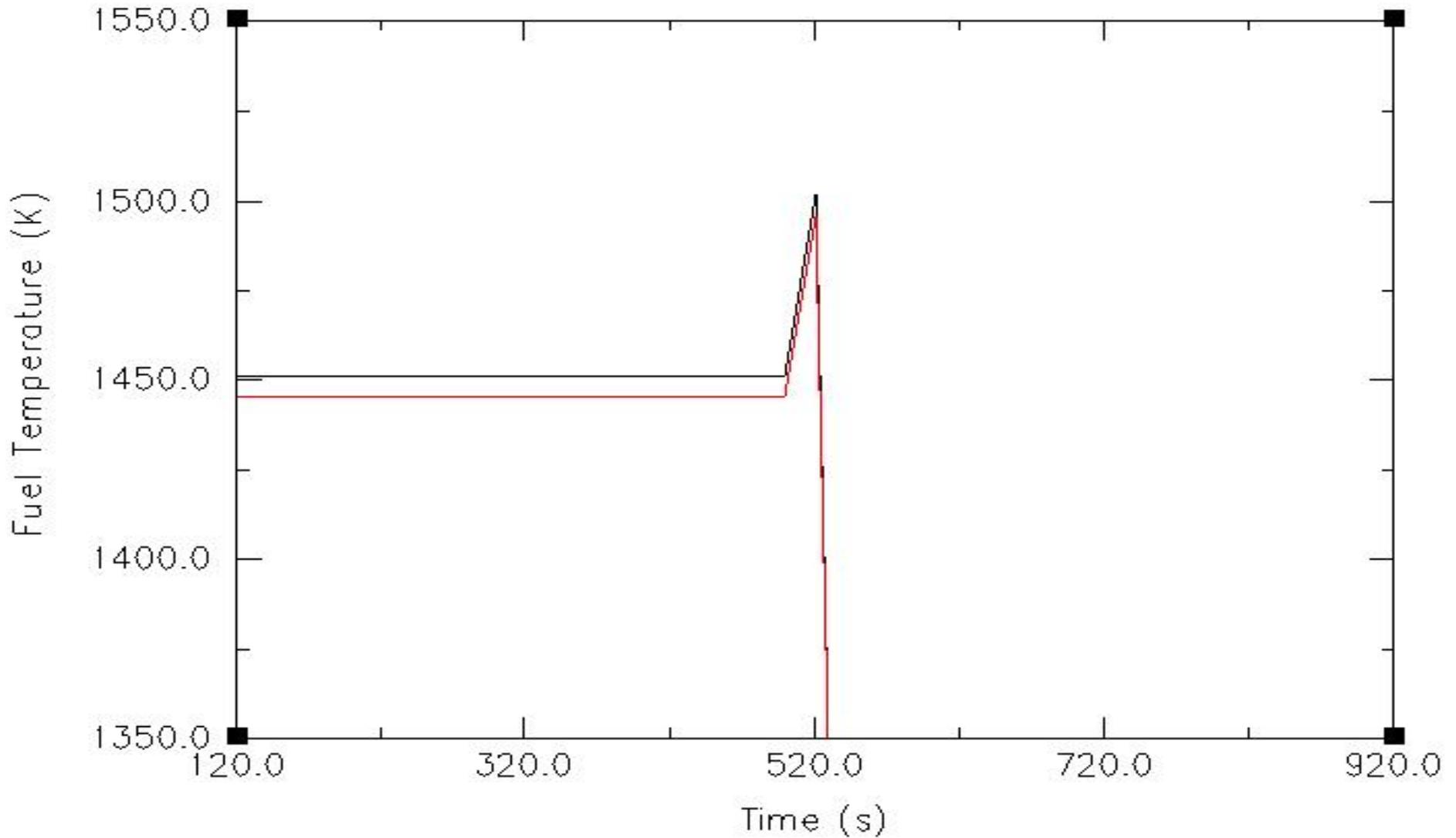
- Liquid salt vault acts as thermal battery
- Salt vault enables clustering of reactors
- Salt selection and salt vault size can be optimized for differing applications
  - 125 MWt-hr storage @ 600°C requires ~ 13 meter cubic salt tank



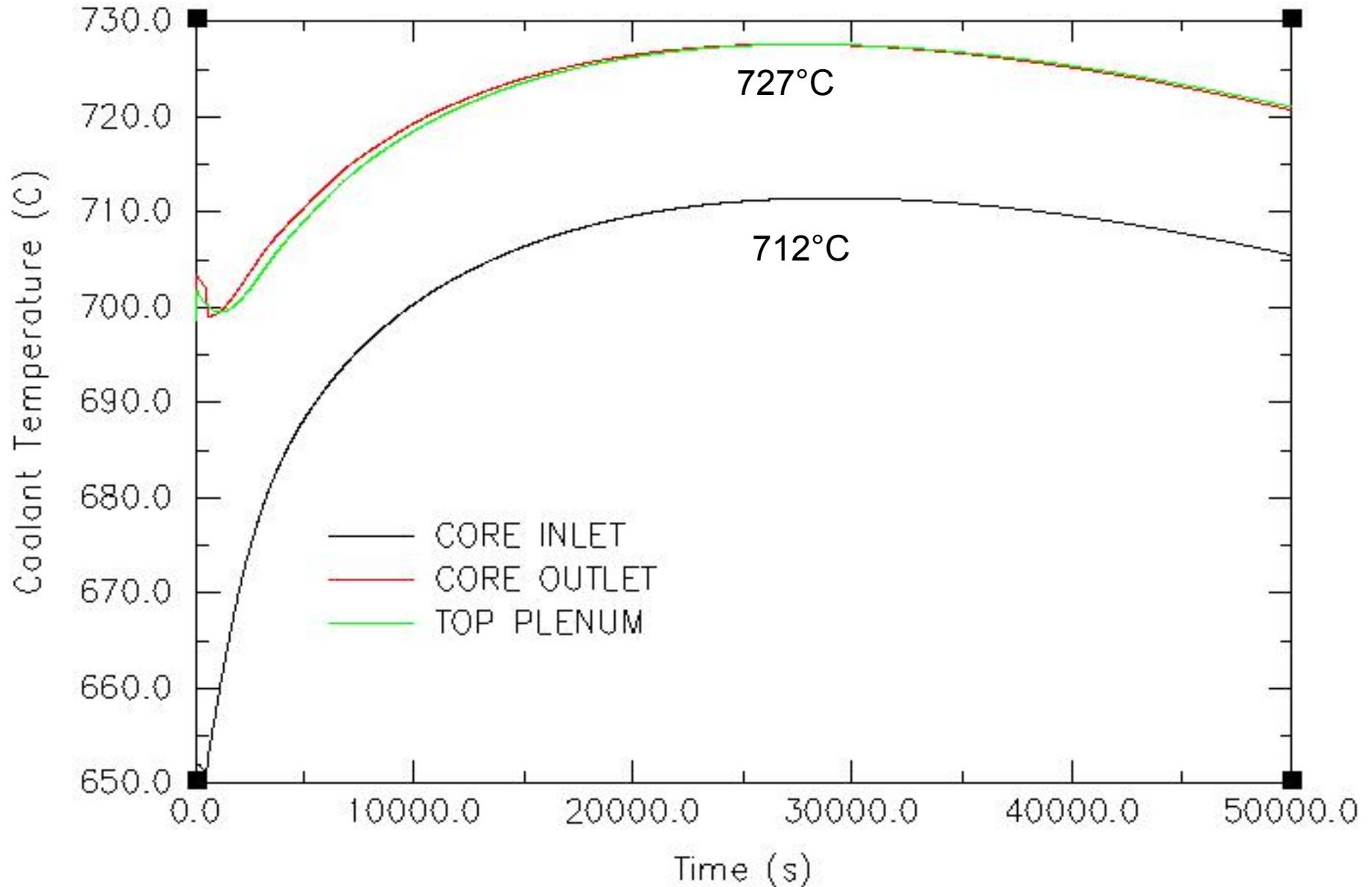
# Peak center-line fuel temperatures during normal operations are acceptable



# Peak fuel temperatures for Alpha Transient (20 s pump coast-down with 10 s scram delay) only increase $\sim 50$ °C



# Two DRACS loops limit coolant temperature rise to less than 30°C



# A SmAHTR materials technology evolution strategy is in development

System Element	@ 700 °C	@ 850 °C	@ 1000 °C
Graphite Internals	Toyo Tanso IG110 or 430	Toyo Tanso IG110 or 430	Toyo Tanso IG110 or 430
Reactor Vessel	Hastelloy-N	<ul style="list-style-type: none"> <li>•Ni-weld overlay on 800H</li> <li>•Insulated low-alloy steel</li> <li>•New Ni-based alloy</li> </ul>	<ul style="list-style-type: none"> <li>• Interior-insulated low-alloy steel</li> </ul>
Core barrel & other internals	Hastelloy-N	<ul style="list-style-type: none"> <li>•C-C composite</li> <li>•New Ni-based alloy</li> </ul>	<ul style="list-style-type: none"> <li>•C-C composite</li> <li>•SiC-SiC composite</li> <li>•New refractory metal</li> </ul>
Control rods and internal drives	<ul style="list-style-type: none"> <li>•C-C composites</li> <li>•Hastelloy-N</li> <li>•Nb-1Zr</li> </ul>	<ul style="list-style-type: none"> <li>•C-C composites</li> <li>•Nb-1Zr</li> </ul>	<ul style="list-style-type: none"> <li>•C-C composites</li> <li>•Nb-1Zr</li> </ul>
PHX & DRACS	Hastelloy-N	<ul style="list-style-type: none"> <li>•New Ni-based alloy</li> <li>•Double-sided Ni cladding on 617 or 230</li> </ul>	<ul style="list-style-type: none"> <li>•C-C composite</li> <li>•SiC-SiC composite</li> <li>•Monolithic SiC</li> </ul>
Secondary (salt-to-gas) HX	Coaxial extruded 800H tubes with Ni-based layer	<ul style="list-style-type: none"> <li>•New Ni-based alloy</li> <li>•Coaxial extruded 800H tubes with Ni-based layer</li> </ul>	?

# Summary

- **SmAHTR is an “entry-level” VHTR concept**
- **SmAHTR concept explores the small FHR design space**
- **SmAHTR concept is not optimized**
  - Many design trades still to be evaluated
- **SmAHTR design objectives:**
  - address near-term process heat and electricity applications
  - enable long-term evolution to higher efficiency electric generation and higher temperature process heat applications
- **SmAHTR integrates architectures and technologies of MSR, GCR, LMR, and integral LWR systems**